Favorable discharge disposition and survival after successful endovascular repair of ruptured abdominal aortic aneurysm

Gabriel A. Wallace, MD,[a] Benjamin W. Starnes, MD,[a] Thomas S. Hatsukami, MD,[a] Elina Quiroga, MD,[a] Gale L. Tang, MD,[b] Ted R. Kohler, MD,[b] and **Nam T. Tran, MD,[a]** *Seattle, Wash*

Objective: **Endovascular repair of ruptured abdominal aortic aneurysm (rEVAR) has been shown to improve perioperative outcomes compared with open surgical repair (OSR). Follow-up of these patients, however, is lacking. In this study, we compare the discharge disposition and midterm survival of ruptured aneurysm patients who survived treatment with either rEVAR or OSR.**

Methods: **We performed an institutional review board-approved, single-institution, retrospective review of all patients with ruptured abdominal aortic aneurysms (rAAAs) admitted from July 2007 to February 2012. Primary outcomes were discharge disposition and midterm survival (>30 days after the index operation). We also evaluated compliance with follow-up and prevalence of endoleak.**

Results: **A total of 118 patients were analyzed. Eight patients received only comfort care, 10 died in the operating room, 39 underwent OSR, and 61 had rEVAR. Average age and sex were similar (OSR, 77 ± 7.8 years, 85% male; rEVAR, 74 ± 7.4 years, 79% male). Seventy-two survived to discharge (54% OSR [21/39]; 84% rEVAR [51/61]; *P* = .001). OSR patients had longer lengths of intensive care unit and total length of stay than rEVAR (11.8 ± 10.4/23 ± 16.4 days vs 6.3 ± 8.5/12.3 ± 13.0 days; *P* = .002/.02). Only 19% (4/21) of patients were discharged home after OSR, rather than to a skilled nursing facility. Significantly more rEVAR patients were discharged to home rather than a skilled nursing facility (65%; 33/51) (*P* = .0004). Overall, the follow-up rate for determination of survival for patients who lived past 30 days was 86% (56/65; median, 14 months; 25th-75th interquartile, 3.1-27.8). Multivariable logistic regression revealed only the type of procedure performed and perioperative hypotension predicted discharge destination. Kaplan-Meier analysis revealed a significant midterm survival benefit for patients after rEVAR compared with OSR (*P* = .01, log-rank). Subgroup analysis of survivors past 30 days revealed similar rates of midterm survival (*P* = .7, log-rank). Overall, midterm relative risk reduction for death after rEVAR vs OSR was 35% (95% confidence interval, 0.06-0.59).**

Conclusions: **We have previously demonstrated that successful utilization of rEVAR improves the early survival of rAAA patients compared with OSR. This study shows that more patients are able to be discharged to home after rEVAR and that the early survival advantage is continued in midterm follow-up, suggesting that rEVAR should be attempted first when feasible. Further studies are needed to determine the long-term durability of endovascular repair in the management of rAAA as well as the impact on cost and long-term quality of life. (J Vasc Surg 2013;57:1495-502.)**

Although endovascular repair of ruptured abdominal aortic aneurysms (rEVAR) was shown to be technically feasible almost 20 years ago, only in the past decade has it become an accepted approach.[1-3] The data in support of rEVAR are compelling but are mainly retrospective perioperative and early outcome investigations.[4-8] Despite the large amount of data favoring rEVAR in terms of early survival, studies evaluating midterm outcomes of rEVAR are limited and have shown mixed results.[9-11] A recent study comparing 37 patients who underwent rEVAR and 111 propensity matched patients who underwent OSR demonstrated no mid- or late-term survival advantage for rEVAR. More studies are needed to determine if the improved early outcomes following rEVAR are limited or can extend into the mid- and later-term follow-up compared with OSR.[12-15]

Our early experience with rEVAR has been encouraging. In 2010, we reported a highly significant reduction in 30-day mortality following the implementation of a structured rEVAR-first algorithm (35% relative risk reduction).[16]

The purpose of this study is to determine the effect of rEVAR vs OSR on the discharge disposition, midterm survival, endoleak prevalence, and follow-up of patients who survived initial repair of a ruptured abdominal aortic aneurysm (rAAA).

METHODS

This is a single-institution, retrospective review that was approved by the institutional review board at the

From the Division of Vascular Surgery, University of Washington School of Medicine[a]; and the Division of Vascular Surgery, Veteran Affairs Puget Sound Health Care System, University of Washington Medical School.[b]

Author conflict of interest: none.

Presented at the Twenty-seventh Annual Meeting of the Western Vascular Society, Scientific Session, Park City, Utah, September 25, 2012.

Reprint requests: Nam T. Tran, MD, Division of Vascular Surgery, Harborview Medical Center, 325 Ninth Ave, Box 339908, Seattle, WA 98104 (e-mail: nam@uw.edu).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214/$36.00

http://dx.doi.org/10.1016/j.jvs.2012.11.089

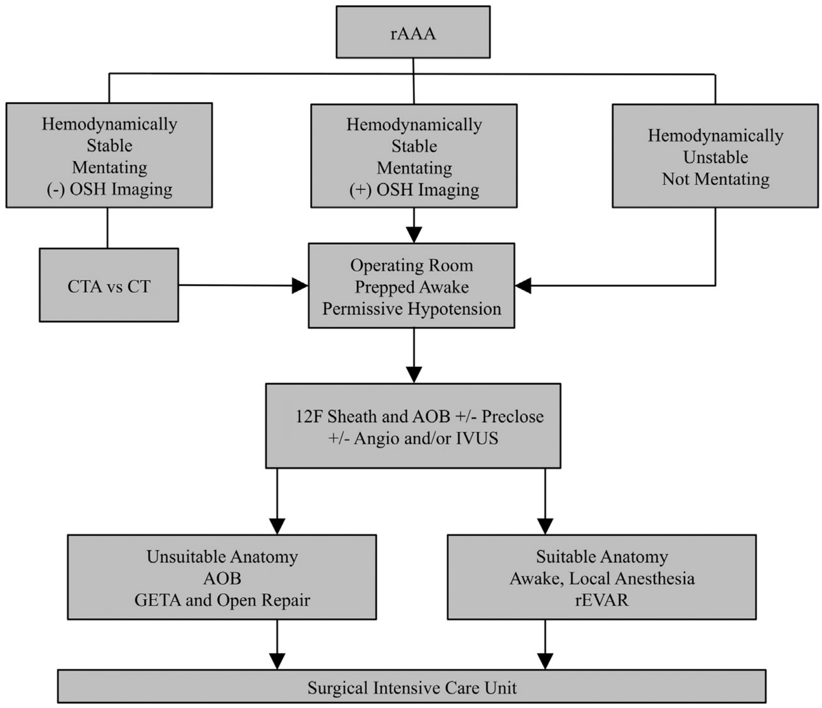


Fig 1. Structured algorithm for managing patients with ruptured abdominal aortic aneurysms (*rAAAs*). *AOB,* Aortic occlusion balloon; *CT,* computed tomography; *CTA,* computed tomographic angiography; *GETA,* general endotracheal anesthesia; *IVUS,* intravascular ultrasound; *OSH,* outside hospital; *rEVAR,* endovascular repair of ruptured abdominal aortic aneurysm.

University of Washington. All consecutive patients admitted to Harborview Medical Center with the diagnosis of rAAA between July 1, 2007 and February 15, 2012 were included. This time period followed the implementation of a structured and previously described rEVAR-first protocol (Fig 1).[16] Briefly, patients are differentiated based on hemodynamics and mentation. We allow for permissive hypotension as long as patients are mentating. A computed tomography (CT) scan is obtained for stable patients who do not have imaging. Patients with imaging or who are unstable go directly to the operating room (OR), bypassing the emergency department. Once in the OR, an aortic occlusion balloon is placed and inflated to profile for those patients with hemodynamic instability. rEVAR is attempted first in all patients with suitable anatomy and appropriate patients are done under local or no anesthesia. Decompression laparotomy is performed for abdominal compartment syndrome when indicated. In these cases, the retroperitoneal space is not opened, and the retroperitoneal hematoma not evacuated. The abdomen is left open and the patient is taken back to the operating room every 1-2 days until fascial closure is achieved. All patients are admitted to the surgical intensive care unit postoperatively.

Demographic, perioperative, and follow-up characteristics were assessed including age, sex, zip code, preoperative hypotension (defined as a single systolic blood pressure <90 mm Hg), admission arterial lactate level, hospital and intensive care unit (ICU) length of stay (LOS), clinical follow-up dates, CT angiography obtained at follow-up, secondary procedures and reintervention, discharge destinations, and dates of death. Days in the ICU following rEVAR or OSR until transfer to the surgical floor were included in the determination of ICU LOS. Factors influencing 30-day survival were reviewed and analyzed in a previous publication from our institution.[16] Patients discharged alive who had not had a recent clinic appointment with us were determined to be dead or alive by search of a national death certificate database. If they were not found in this database, telephone contact was attempted twice using the contact information in their medical record. Patients who were unable to be contacted were censored at the time of last known contact.

Primary endpoints were discharge destination and Kaplan-Meier survival. Secondary endpoints included clinical follow-up, presence of endoleak (for patients who underwent rEVAR), and complications after discharge following open repair. LOS, survival, and discharge disposition were compared in rEVAR patients who did or did not require either decompression laparotomy or femoral-femoral bypass.

Categorical demographic variables were analyzed using χ^2 analysis. Continuous parametric demographic variables were evaluated using an unpaired, two-tailed Student *t*-test. Nonparametric variables were compared using the Mann-Whitney test. Multivariable logistic regression and Kaplan-Meier survival distribution analysis were performed

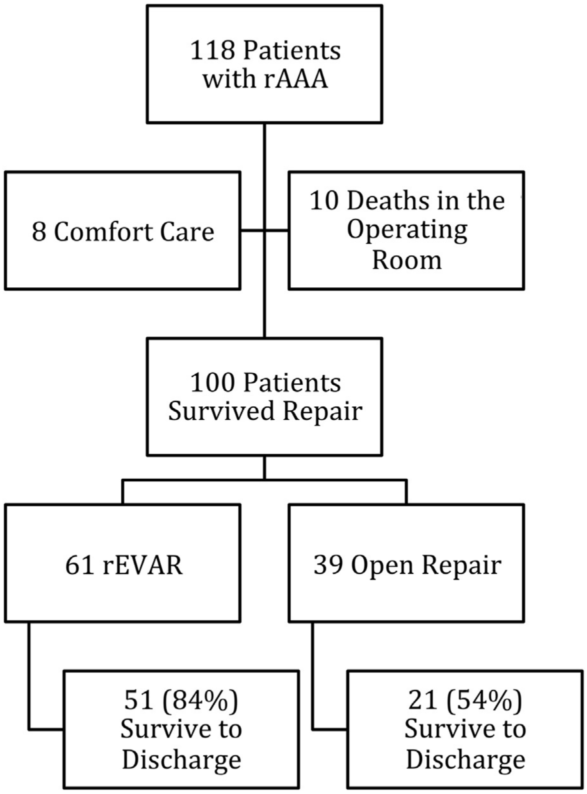


Fig 2. Patient inclusion and exclusion for analysis. *rAAA,* Ruptured abdominal aortic aneurysm; *rEVAR,* endovascular repair of ruptured abdominal aortic aneurysm.

using the XLSTAT (Addinsoft Inc, New York, NY) statistical package for Microsoft Excel. *P* values of <.05 were considered statistically significant for all analyses.

RESULTS

A total of 118 patients were admitted to our facility with the diagnosis of rAAA during the study period (Fig 2). Eight patients (6.8%) underwent comfort care, a decision that was made for patients who had a living will or by a legal surrogate who was in contact with our team. Ten patients (8.5%) died in the operating room prior to or during attempted repair; these were patients who presented in extremis and, despite an attempt to save their lives, died as detailed in Table I. One hundred patients survived the index operation; 39 underwent OSR and 61 were treated with rEVAR. The average age of the open group was 77 ± 7.8 years with 33 male patients (85%), and the average age of the endovascular group was 74 ± 7.4 years with 48 male patients (79%) (Table II). Seven of the 39 OSR group had been converted to open repair after a failed endovascular attempt: five due to unfavorable anatomy, specifically tortuosity and extensive calcification of the iliac arteries, one due to loss of pulse with an aortic occlusion balloon in place, and one taken back on postoperative day zero for surgical evaluation of continued bleeding and hemodynamic instability. Of the conversions, only one survived to discharge (14% perioperative survival). In the endovascular group, four patients underwent concomitant decompression laparotomy, one patient underwent both decompression laparotomy and femoral-femoral bypass, and seven patients underwent uni-iliac rEVAR with femoral-femoral bypass.

Preoperative hypotension was present in 64% (25/39) of the OSR group and 62% (38/61) of the rEVAR patients ($P = .85$). Admission arterial lactate levels were on average elevated and similar between patients who underwent OSR compared with rEVAR (4.8 ± 4.0 vs 3.9 ± 3.4 mmol/L; $P = .45$). Admission lactic acidosis was similar between survivors to discharge following OSR and rEVAR (2.7 ± 2.8 vs 3.2 ± 2.6 mmol/L; $P = .51$).

Seventy-two of the 100 patients who survived the index operation survived to discharge: 54% (21/39) after OSR and 84% after rEVAR (51/61) ($P = .001$). Average hospital LOS was 12.3 ± 13.0 days for the rEVAR group and 23 ± 16.4 days for the OSR group ($P = .002$). Average ICU LOS following rEVAR was 6.3 ± 8.5 days and after OSR was 11.8 ± 10.4 days ($P = .02$). Patients who underwent rEVAR alone had significantly shorter hospital LOS than patients who also underwent decompression laparotomy or femoral-femoral bypass (10.1 ± 11.6 vs 21.4 ± 15.3 days; $P = .01$).

Of those who survived to discharge, 51% (37/72) went home and 49% (35/72) were discharged to a skilled nursing facility (SNF). The majority of rEVAR patients were discharged home (65%, 33/51) vs 19% (4/21) of the OSR group ($P = .0004$) (Fig 3). A significantly higher proportion of patients who underwent femoral-femoral bypass or decompression laparotomy at the time of rEVAR were discharged to an SNF compared with patients who underwent rEVAR alone (67% vs 29%; $P = .001$). Patients who underwent strictly rEVAR on average had a shorter LOS than patients who underwent additional procedures (10.1 ± 11.6 vs 21.4 ± 15.3 days; $P = .01$). Patients who underwent decompression laparotomy in addition to rEVAR were less likely to survive to discharge compared to rEVAR without decompression (60% vs 86%).

Twenty-three patients died after discharge from the hospital. Seven of these patients died within 30 days of discharge, three (14.3%) in the open surgical group, and four (7.8%) in the endovascular group. Unfortunately, the cause of death was not determined in this group. Of the 16 that died after 30 days, four were in the open surgical group (death at postoperative month 1.8, 26, 35, and 47) and 12 were in the endovascular group (six within the first 6 months, three within the second 6 months, and three at 21, 29, and 42 months). A significantly higher proportion of rEVAR patients discharged to an SNF vs home died in the follow-up period (61% vs 18% of deaths; $P = .003$).

Overall, the follow-up rate for determination of survival for patients who lived past 30 days was 86% (56/65) with a median length of follow-up of 14 months (25th-75th interquartile, 3.1-27.8). Median follow-up after rEVAR was 16.3 months and after OSR was 12.4 months

Table I. Summary of excluded intraoperative deaths

Patient	*Intervention*	*Events leading to intraoperative death*
1	Aortic control	AOB placed, balloon dependent, inner cool IVC catheter placed, laparotomy, AOB rupture, manual aortic control, AOB replaced, aneurysm sac entered, death
2	Aortic control	Arrested on transfer to OR table, AOB unable to be placed, laparotomy, manual aortic control, CPR, death
3	Aortic control	AOB unable to be placed, ongoing CPR, laparotomy, aortic control, death
4	Aortic control	Arrested on transport from CT, AOB placed, death
5	Aortic control	Laparotomy, cross-clamp, death
6	Aortic control	Arrested on transfer to OR table, 40 minutes CPR, attempted AOB, death
7	Attempted OSR	Arrested with proximal aortic dissection, arrested with distal anastomosis, significant bleeding from proximal anastomosis, five cycles CPR, 2 hours intermittent supraceliac clamp time, death
8	Attempted OSR	AOB unable to be placed, laparotomy, manual proximal aortic control, arrested, coagulopathic and hypothermic to 30°C, arrested and died as proximal anastomosis completed
9	Attempted rEVAR	rEVAR, remained balloon dependent, TEE consistent with MI, decompression laparotomy, intraoperative family discussion revealed the patient had metastatic cancer and had hoped to die from rupture of known AAA, AOB deflated, death
10	Attempted rEVAR	AOB placed and balloon dependent, arrested before device deployment, device deployed, decompression laparotomy, death

AAA, Abdominal aortic aneurysm; *AOB,* aortic occlusion balloon; *CPR,* cardiopulmonary resuscitation; *CT,* computed tomography; *IVC,* inferior vena cava; *MI,* myocardial infarction; *OR,* operating room; *OSR,* open surgical repair; *rEVAR,* endovascular repair of ruptured abdominal aortic aneurysm; *TEE,* transesophageal echocardiography.

Table II. Demographic characteristics of patients that survived their index procedure for rAAA

	OSR (n = 39)	*rEVAR (n = 61)*	P
Age ± SD, years	77.4 ± 7.8	74.4 ± 7.4	.069
Age >80 years	18 (46)	13 (21)	<.01
Sex			
Males	33 (85)	48 (79)	.46
Females	6	13	
Preoperative hypotension (SBP <90 mm Hg)	25 (64)	38 (62)	.85
Admission arterial lactate ± SD, mmol/L	4.8 ± 4.0	3.9 ± 3.4	.45
Length of stay ± SD, days	23 ± 16.4	12.3 ± 13.0	<.01
ICU length of stay ± SD, days	11.8 ± 10.4	6.3 ± 8.5	.02
Transfer from OSH	20 (51)	40 (66)	.15
Median prehospital time, hours (25th-75th interquartile)	8.8 (2.0-18.0)	2.8 (1.2-16.1)	.30
Median prehospital time to our institution, hours (25th-75th interquartile)	14.4 (6.6-19.7)	6.8 (4.2-22.3)	.20
Median distance from our institution, miles (25th-75th interquartile)	39.4 (14.5-63.3)	20.3 (11.8-51.0)	.29
Antecedent aortic intervention	4 (10)	7 (11)	.85
Survival to discharge	21 (54)	51 (84)	<.01
30-day survival	18 (46)	47 (77)	<.01
Median f/u for determination of midterm survival, months (25th-75th interquartile)	16.3 (3.1-27.9)	12.4 (3.1-24.8)	.8
Median clinical follow-up, months (25th-75th interquartile)	0.9 (0.5-2)	1.6 (1.0-10.8)	.14

f/u, Follow-up; *ICU,* intensive care unit; *OSH,* outside hospital; *OSR,* open surgical repair; *rAAA,* ruptured abdominal aortic aneurysm; *rEVAR,* endovascular repair of ruptured abdominal aortic aneurysm; *SBP,* systolic blood pressure; *SD,* standard deviation.
Mean prehospital time was defined as time from symptom onset to admission at any hospital. Mean prehospital time to our institution was defined as time from symptom onset to admission at our hospital, including time spent at outside hospitals beforehand.
Continuous data are given as median (range) and categoric data as number (%).

(respective 25th-75th interquartile, 3.1-27.9, 3.1-24.8). Clinically, we saw 61% patients back (44/72), with a median clinical follow-up of 1.5 months (25th-75th interquartile, 0.56-10.2). Nine patients who did not have a recent visit to our facility could not be contacted and were not in the death certificate database. These patients were censored at the last contact.

Fourteen endoleaks were discovered among 31.7% (13/41) of rEVAR patients who underwent postoperative imaging. Two were type I and were repaired with endovascular techniques during the initial admission for rAAA. An additional patient was found to have both type I and III, which were also repaired during the initial admission. The majority of the remaining endoleaks were type II (n = 9) and type III (n = 1). The patient with the type III endoleak was taken to the angiography suite where an angiogram could not detect the endoleak found on CT scan. Therefore, the patient was treated conservatively. All type II endoleaks were treated conservatively, as their sac diameter did not increase.

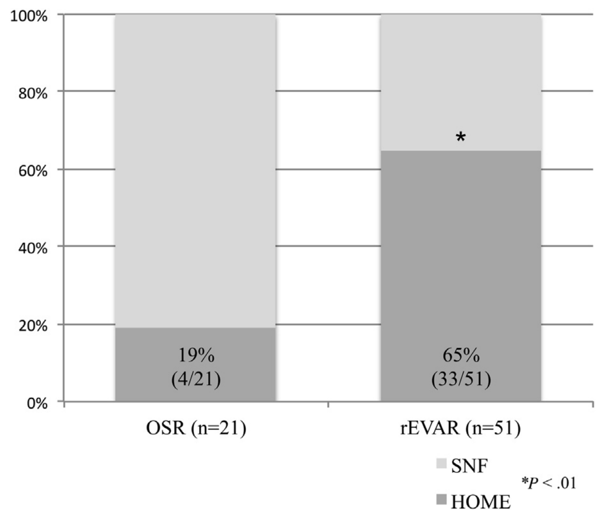


Fig 3. Discharge disposition after endovascular repair of ruptured abdominal aortic aneurysms (*rEVARs*) vs open surgical repair (*OSR*). *SNF,* Skilled nursing facility.

Six patients in the endovascular group returned to our facility for secondary interventions: one for enterocutaneous fistula and small bowel resection, one for groin infection requiring exploration and sartorius flap, one for type II endoleak for which the patient declined repair, one for infected retroperitoneal hematoma, and two for infected femoral-femoral bypass that ultimately required explant and redo bypass. Three patients from the OSR group returned to our facility for secondary interventions: one with an aortoduodenal fistula and graft infection, another with a graft infection requiring excision, and one with an acute gastrointestinal bleed and acute renal failure shortly after discharge.

Multivariate logistic regression revealed that only the type of procedure performed (rEVAR: odds ratio, 9.96; 95% confidence interval [CI], 2.4-41.3; $P = .002$) and absence of preoperative hypotension (odds ratio, 3.77; 95% CI, 1.0-14.0; $P = .042$) were predictive of discharge to home, while age (over or under 80), sex, distance from our facility, time from symptom onset to presentation at our facility, and previous aortic endovascular or open repair did not have a significant effect.

Kaplan-Meier life table analysis revealed that midterm survival was significantly higher after rEVAR compared with OSR ($P = .01$, log-rank) (Fig 4, *A*). Subgroup survival analysis evaluating only those patients who survived past 30 days found similar midterm survival between groups ($P = .7$, log-rank).

The 30-day absolute risk reduction for death after rEVAR compared with OSR in patients with rAAAs who survived their initial operative intervention was 31% (95% CI, 0.12-0.48) with a relative risk reduction of 57% (95% CI, 0.21-0.90). The overall midterm absolute risk reduction and relative risk reduction for death after rEVAR compared with open OSR were 25% and 35%, respectively (95% CI, 0.04-0.42 and 0.06-0.59, respectively).

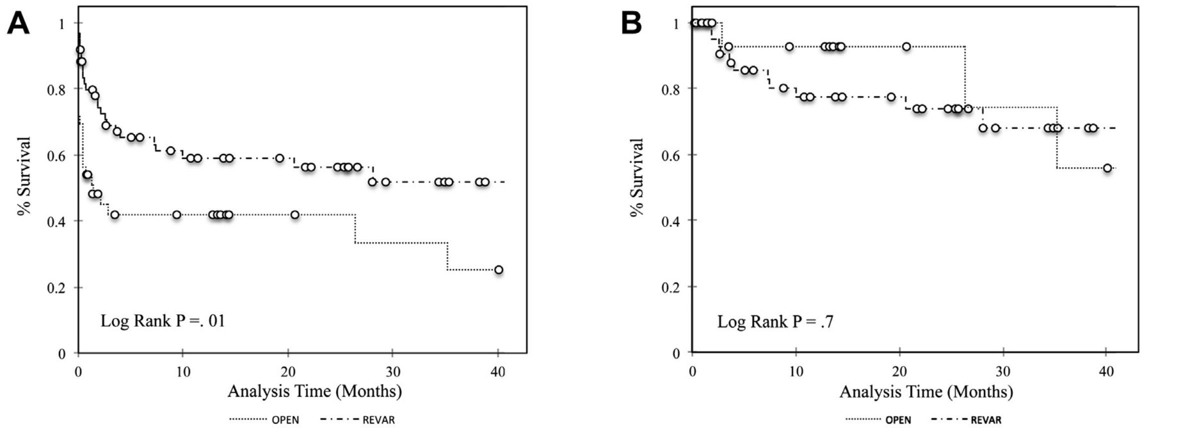
DISCUSSION

There are now several reports, including our own, demonstrating that rEVAR has improved perioperative and early survival from rAAA.[4-8,16] The perioperative and 30-day survival benefit with rEVAR compared with OSR in this series is commensurate with the reduction in early mortality realized in our previously published results.[16] The critical questions now are the following: does this early survival benefit persist through longer follow-up, is it applicable to all patients able who successfully undergo rEVAR, and how does the type of procedure affect other aspects of these patients' postoperative recovery?

Patients who underwent rEVAR were significantly more likely to discharge to home rather than an SNF compared with those who underwent OSR. To our knowledge, this is the first report examining the effect of repair type on discharge disposition and highlights the physiologic benefit of an endovascular approach to this extremely morbid condition.[17] *Our patients were 10 times more likely to go home after rEVAR*. Hypotension, which is a marker for the degree of physiologic insult, was the only other predictor for discharge to a SNF. The biologic and psychosocial benefits of rEVAR, including the immediate ability to ambulate, return to a normal level of independence, and discharge to home rather than a SNF need further study to determine its full impact on quality of life. We are currently undertaking such studies using validated questionnaires.

We further analyzed the significance of a strictly endovascular approach vs that of "hybrid" procedures (ie, only rEVAR compared with endovascular repair with concomitant decompression laparotomy and/or femoral-femoral arterial bypass) in an effort to emphasize the benefit of standalone endovascular technique. This revealed significantly favorable outcomes following the strictly endovascular approach compared with the "hybrid" approach including shorter hospital LOS (10.1 ± 11.6 vs 21.4 ± 15.3 days; $P = .01$) and a lower incidence of discharge to an SNF (29% vs 67%; $P = .001$). Patients who underwent decompression laparotomy were also more likely to die in the hospital, likely because of the greater severity of their physiologic insult.

Kaplan-Meier survival analysis revealed that the significantly improved midterm survival of patients treated with rEVAR compared with OSR is consistent with the early survival benefit our rEVAR patients have realized. Subsequent Kaplan-Meier group comparison of the subgroup of patients who lived past 30 days provides further evidence that the midterm survival benefit of rEVAR is attributable to the immediate survival advantage afforded by rEVAR compared with OSR ($P = .7$, log-rank) (Fig 4, *B*). Those who survive the physiologic challenge of rupture and repair appear to have similar survival. rEVAR allows more of our patients to survive the initial challenge of aneurysm rupture and repair and to enter the follow-up period. It is important to note that patients who were able to undergo rEVAR may have had more favorable anatomy than the OSR group, in particular, less juxtarenal involvement.



Months	0	10	20	30	40
At Risk: rEVAR	61	28	21	11	6
At Risk: OSR	39	12	6	5	3
SEM	–	.067	.069	.076	.11

Months	0	10	20	30	40
At Risk: rEVAR	47	28	21	11	6
At Risk: OSR	18	12	6	5	3
SEM	–	.067	.073	.087	.14

Fig 4. A, Midterm survival of patients after endovascular repair of ruptured abdominal aortic aneurysms (*rEVARs*) or open surgical repair (*OSR*) for ruptured abdominal aortic aneurysm (rAAA) (all patients surviving the index procedure). **B,** Midterm survival of patients after rEVAR or OSR for rAAA (patients that survived >30 days postdischarge). *SEM,* Standard error of the mean.

This potential bias against OSR could only be controlled for in a randomized trial, which is both impractical and, given the benefits of EVAR in terms of perioperative and midterm survival, unethical. Our findings argue strongly for the "rEVAR first" policy we have described.

Midterm survival may be improved with rEVAR, but we cannot definitively say that morbidity improved as well. Strict follow-up is mandatory to monitor for device complications such as stent strut fractures, thrombosis, endoleak, or endograft migration. Patients who underwent rEVAR may be more susceptible to these complications than patients who undergo elective EVAR because of the urgent conditions that preclude advanced planning and the ability to obtain optimal imaging prior to surgery, resulting on reliance of alternative techniques like intravascular ultrasound, arteriography, and noncontrast CT scans, which could in turn lead to a number of patients treated outside the instructions for use for the device utilized.[18-21]

The 2009 Society for Vascular Surgery guidelines for care of patients with AAAs do not detail a recommended follow-up protocol for patients that survive rEVAR for rAAA.[22] Although the significantly shorter hospital (particularly ICU) course may initially be economically favorable after rEVAR compared with OSR, the lifelong follow-up and serial CT evaluation after rEVAR may have high economic cost, is not without risks such as radiation and contrast burden, and may be an inconvenience to patients who have not agreed in advance to interact with the medical system in this manner for the remainder of their lives (Fig 5).[23,24] In this group of patients, follow-up often was not achieved.

As the regional referral center for five states with the largest land mass catchment area in the United States, we have the opportunity to see a large number of patients with aortic pathology. However, our broad catchment area also introduces limitations. Although our follow-up for determination of survival was reasonable, we were unable to account for all of our patients after discharge, and even those we did account for often had suboptimal clinical follow-up. Many of our patients receive follow-up care after rAAA locally and are subsequently lost to our practice. Problems with follow-up are not unique to our institution and highlight a major challenge in determining whether rEVAR is superior to or safer than OSR in the long term. Lack of sufficient follow-up makes it difficult to determine the true number of endovascular complications in our group, and we were unable to determine a reliable reintervention rate or the cause of death for the patients who died outside of our institution. The sample size of patients with follow-up blood chemistries was too small to draw meaningful conclusions with regard to changes in renal function following rEVAR. Additionally, we do not know the total number of rAAA patients in our catchment area who were treated in the community or died before reaching our facility.

Our findings, while encouraging, may not be generalizable to other practices. As a regional referral center for acute aortic pathology, our institution has a team trained and on-call for vascular emergencies 24 hours a day, a full inventory of stent grafts, and staff accustomed to caring for critically ill surgical patients.[25-27] Although a recent article has contrarily suggested that rEVAR has comparable result to OSR, the study was unfortunately limited by a large percentage of loss to follow-up of those who underwent open repair.[10] Notably, less than 15% of their patients underwent rEVAR compared with the

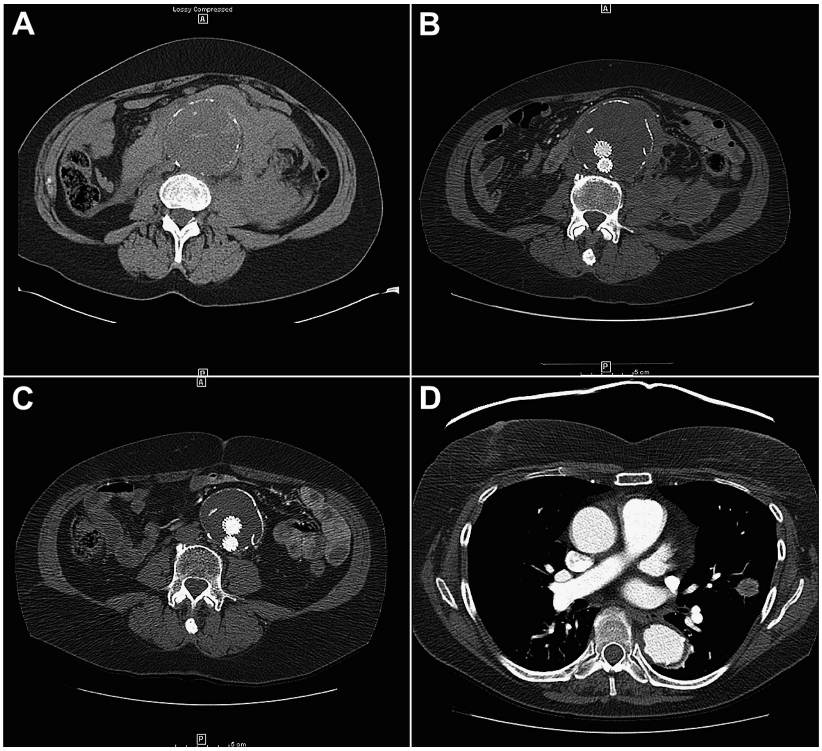


Fig 5. Representative ruptured abdominal aortic aneurysm (rAAA) and follow-up images. **A,** This 61-year-old female who lived 53 miles from our hospital was woken from sleep by an acute abdominal pain. She was admitted to an outside hospital where this noncontrast computed tomography (CT) angiography revealed an rAAA. She was transferred to our hospital and underwent successful endovascular repair of ruptured abdominal aortic aneurysm (rEVAR). **B,** Postoperative CT angiography 3 weeks later demonstrated exclusion of the aneurysm sac without endoleak. **C,** Two-year follow-up CT angiography revealed decreasing sac diameter. **D,** Two-year follow-up CT angiography of the chest revealed an incidental left upper lobe lung nodule that unfortunately turned out to be biopsy-proven adenocarcinoma. The patient is currently undergoing oncologic workup.

majority of ours. Additionally, these authors did not utilize a structured protocol.[28] We have adopted an endovascular-first strategy using aortic occlusion balloons to help control patients with hemodynamic instability, demonstrating that patients with hemodynamic instability can be treated using rEVAR with good results. Finally, although not statistically significant, they did have a trend toward improved early survival following rEVAR and may not have had the volume of rEVAR patients to reach statistical significance.

Our data show that rEVAR saves lives and support the utilization of rEVAR over OSR for the treatment of rAAA when resources, surgeon expertise, and anatomy allow. More patients are discharged to home after rAAA without the burden of rehabilitating from a laparotomy incision or convalescing in an SNF after rEVAR. A significantly greater proportion of patients treated with rEVAR survived to midterm follow-up than those treated with OSR. Importantly, the midterm endoleak incidence and significance, and the long-term durability of rEVAR still remain to be determined. As endovascular surgery becomes increasingly more prevalent, an effort must be made to continue to offer the best procedure for each patient whether that be rEVAR or OSR.[29-31]

CONCLUSIONS

The utilization of rEVAR in our institution has improved in-hospital and early survival of patients with rAAAs. We have now demonstrated that a significantly higher proportion of rAAA patients who underwent rEVAR were able to be discharged home compared with OSR. At midterm follow-up, the significant early survival benefit of rEVAR for rAAA prevailed. These outcomes support the utilization of rEVAR over OSR when feasible in centers that are able to achieve the early survival benefit. Continued durability, cost-effectiveness, endoleak incidence and significance, and quality of life associated with rEVAR compared with OSR for rAAA remain to be determined in late-term follow-up.

AUTHOR CONTRIBUTIONS

Conception and design: GW, NT
Analysis and interpretation: GW, NT
Data collection: GW, NT
Writing the article: GW, NT
Critical revision of the article: BS, EQ, GW, GT NT, TH, TK

Final approval of the article: NT
Statistical analyses: GW, NT
Obtained funding: Not applicable
Overall responsibility: NT

REFERENCES

1. Yusef SW, Whitaker SC, Chuter T, Wenham PW, Hopkinson BR. Emergency endovascular repair of leaking aortic aneurysm. Lancet 1994;344:1645.
2. Albuquerque FC, Tonnessen BH, Noll RE, Cires G, Kim JK, Sternbergh WC. Paradigm shifts in the treatment of abdominal aortic aneurysm: trends in 721 patients between 1996 and 2008. J Vasc Surg 2010;51:1348-53.
3. Marin ML, Veith FJ, Cynamon J, Sanchez LA, Lyon RT, Levine BA, et al. Initial experience with transluminally placed endovascular grafts for the treatment of complex vascular lesions. Ann Surg 1995;222: 449-65.
4. Chagpar RB, Harris JR, Lawlor DK, DeRose G, Forbes TL. Early mortality following endovascular versus open repair of ruptured abdominal aortic aneurysms. Vasc Endovascular Surg 2010;44:645-9.
5. Bosch Ten JA, Teijink JA, Willigendael EM, Prins MH. Endovascular aneurysm repair is superior to open surgery for ruptured abdominal aortic aneurysms in EVAR-suitable patients. J Vasc Surg 2010;52:13-8.
6. Davenport DL, O'Keeffe SD, Minion DJ, Sorial EE, Endean ED, Xenos ES. Thirty-day NSQIP database outcomes of open versus endoluminal repair of ruptured abdominal aortic aneurysms. J Vasc Surg 2010;1:305-9.
7. Holst J, Resch T, Ivancev K, Bjorses K, Dias N, Lindblad B, et al. Early and intermediate outcome of emergency endovascular aneurysm repair of ruptured infrarenal aortic aneurysm: a single-centre experience of 90 consecutive patients. Eur J Vasc Endovasc Surg 2009;37:413-9.
8. Mandawat A, Mandawat A, Sosa JA, Muhs BE, Indes JE. Endovascular repair is associated with superior clinical outcomes in patients transferred for treatment of ruptured abdominal aortic aneurysms. J Endovasc Ther 2012;19:88-95.
9. Hinchliffe RJ, Braithwaite BD. Ruptured abdominal aortic aneurysm: endovascular repair does not confer any long-term survival advantage over open repair. Vascular 2007;15:191-6.
10. Saqib N, Park SC, Park T, Rhee RY, Chaer RA, Makaroun MS, et al. Endovascular repair of ruptured abdominal aortic aneurysm does not confer survival benefits over open repair. J Vasc Surg 2012;56:614-9.
11. Mehta M. Invited commentary. J Vasc Surg 2012;56:620.
12. Sarac TP, Bannazadeh M, Rowan AF, Bena J, Srivastava S, Eagleton M, et al. Comparative predictors of mortality for endovascular and open repair of ruptured infrarenal abdominal aortic aneurysms. Ann Vasc Surg 2011;25:461-8.
13. Nedeau AE, Pomposelli FB, Hamdan AD, Wyers MC, Hsu R, Sachs T, et al. Endovascular vs open repair for ruptured abdominal aortic aneurysm. J Vasc Surg 2012;56:15-20.
14. Rayt HS, Sutton AJ, London NJ, Sayers RD, Bown MJ. A systematic review and meta-analysis of endovascular repair (EVAR) for ruptured abdominal aortic aneurysm. Eur J Vasc Endovasc Surg 2008;36: 536-44.
15. Egorova N, Giacovelli J, Greco G, Gelijns A, Kent CK, McKinsey JF. National outcomes for the treatment of ruptured abdominal aortic aneurysm: comparison of open versus endovascular repairs. J Vasc Surg 2008;48:1092-100.
16. Starnes BW, Quiroga E, Hutter C, Tran NT, Hatsukami T, Meissner M, et al. Management of ruptured abdominal aortic aneurysm in the endovascular era. J Vasc Surg 2010;51:9-18.
17. Makar RR, Badger SA, O'Donnell ME, Loan W, Lau LL, Soong CV. The effects of abdominal hypertension after open and endovascular repair of a ruptured abdominal aortic aneurysm. J Vasc Surg 2009;49: 866-72.
18. Aburahma AF, Campbell JE, Mousa AY, Hass SM, Stone PA, Jain A, et al. Clinical outcomes for hostile versus favorable aortic neck anatomy in endovascular aortic aneurysm repair using modular devices. J Vasc Surg 2011;54:13-21.
19. AbuRahma AF, Campbell J, Stone PA, Nanjundappa A, Jain A, Dean LS, et al. The correlation of aortic neck length to early and late outcomes in endovascular aneurysm repair patients. J Vasc Surg 2009;50:738-48.
20. Richards T, Goode SD, Hinchliffe R, Altaf N, MacSweeney S, Braithwaite B. The importance of anatomical suitability and fitness for the outcome of endovascular repair of ruptured abdominal aortic aneurysm. Eur J Vasc Endovasc Surg 2009;38:285-90.
21. Abbruzzese TA, Kwolek CJ, Brewster DC, Chung TK, Kang J, Conrad MF, et al. Outcomes following endovascular abdominal aortic aneurysm repair (EVAR): an anatomic and device-specific analysis. J Vasc Surg 2008;48:19-28.
22. Chaikof EL, Brewster DC, Dalman RL, Makaroun MS, Illig KA, Sicard GA, et al. The care of patients with an abdominal aortic aneurysm: the Society for Vascular Surgery practice guidelines. J Vasc Surg 2009;50:S2-49.
23. Prinssen M, Wixon CL, Buskens E, Blankensteijn JD. Surveillance after endovascular aneurysm repair: diagnostics, complications, and associated costs. Ann Vasc Surg 2004;18:421-7.
24. White HA, MacDonald S. Estimating risk associated with radiation exposure during follow-up after endovascular aortic repair. J Cardiovasc Surg 2010;51:95-104.
25. Meguid RA, Brooke BS, Perler BA, Freischlag JA. Impact of hospital teaching status on survival from ruptured abdominal aortic aneurysm repair. J Vasc Surg 2009;50:243-50.
26. Lesperance K, Andersen C, Singh N, Starnes B, Martin MJ. Expanding use of emergency endovascular repair for ruptured abdominal aortic aneurysms: disparities in outcomes from a nationwide perspective. J Vasc Surg 2008;47:1165-71.
27. McPhee J, Eslami MH, Arous EJ, Messina LM, Schanzer A. Endovascular treatment of ruptured abdominal aortic aneurysms in the United States (2001-2006): a significant survival benefit over open repair is independently associated with increased institutional volume. J Vasc Surg 2009;49:817-26.
28. Mehta M, Taggert J, Darling RC III, Chang BB, Kreienberg PB, Paty PSK, et al. Establishing a protocol for endovascular treatment of ruptured abdominal aortic aneurysms: outcomes of a prospective analysis. J Vasc Surg 2006;44:1-8.
29. Cho JS, Kim JY, Rhee RY, Gupta N, Marone LK, Dillavou ED, et al. Contemporary results of open repair of ruptured abdominal aortoiliac aneurysms: effect of surgeon volume on mortality. J Vasc Surg 2008;48:10-8.
30. Schanzer A, Steppacher R, Eslami M, Arous E, Messina L, Belkin M. Vascular surgery training trends from 2001-2007: a substantial increase in total procedure volume is driven by escalating endovascular procedure volume and stable open procedure volume. J Vasc Surg 2009;49: 1339-44.
31. Sachs T, Schermerhorn M, Pomposelli F, Cotterhill P, O'Malley J, Landon B. Resident and fellow experiences after the introduction of endovascular aneurysm repair for abdominal aortic aneurysm. J Vasc Surg 2011;54:881-8.

Submitted Sep 26, 2012; accepted Nov 21, 2012.